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A Vector Autoregression Model of Danish Markets for Pork, Chicken, and Beef

Institute of Food and Resource Economics (FOI)

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A Vector Autoregression Model of Danish Markets

for Pork, Chicken, and Beef

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Abstract

A VAR model of market-clearing quantities and prices of the Danish pork, chicken, and beef markets is formulated, estimated, and tested. Through analyses of the model's impulse response function, and forecast error variance decompositions, it is demonstrated that: (i) The three meats are close substitutes; (ii) chicken and pork market shocks have own-market and cross-market effects that occur rapidly and swiftly, while beef market shocks have more enduring impacts on pork and chicken markets; (iii) prices are in general more endogenous than quantities, and (iv) the price of chicken is much more endogenous than the prices of pork and beef.

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Introduction

Andersen et. al. (2007) note that food demand has traditionally been considered inelastic, and consumption volumes sluggishly respond to changes in prices (Jensen and Toftkær, 2002). Also, EU food production is highly regulated through farm programs, environmental regulations, and trade barriers (among other things) that may lead to sluggish food market responses to market shocks (Andersen et. al. 2007).

Since the mid-1980s, the public has displayed an increasing interest in food safety in Europe, the United States, and other areas of the world. Such well-known food safety scandals as the following have promoted this interest (USFDA 2004, undated; UN-WHO 2006):

- A U.S. salmonella outbreak in milk in 1985 that elicited 16,000 cases of illness;

- The 1995 British outbreak of Creutzfeldt-Jacob disease (from an outbreak of bovine spongiform encelopathy or BSE) that claimed 10 lives;

- Asian flu outbreaks that have claimed more than 140 lives since 2003.

Because of such events, consumers, policy makers, agribusiness agents, and researchers have keener interest on how a food market and markets of product substitutes react to some sort of a disease outbreak or to other market shocks. More specifically, such agents want to know the degrees to which such outbreaks or other market events influence quantities demanded and supplied as well as market price for the product and its substitutes; how the event dynamically elicits price/quantity responses; and the impact on food costs. Agents need indicators on how quickly public confidence in a market impacted by disease, natural disasters, or other shocks of demand or supply can be restored. As well, policy makers could find knowledge on how shock-induced product and price impacts dynamically unfold in order to discern available time frames provided for any remedial policy measures deemed desirable. Dynamic timing of market reactions has important implications for policymakers' formulation of remedial policies to offset undesirable shock-elicited effects, and for agribusiness agents that desire optimal marketing strategies in response to such shock-induced impacts.

Our analysis provides some answers regarding the functioning of the Danish markets for pork, chicken, and beef. The following grid of data provides an idea on the demand and supply profiles of pork, chicken, and beef in Denmark in 2003 (Statistics Denmark).

	Domestic production (mio.kg.)	Of which: Exports	Domestic consumption (mio.kg.)	Of which: Imports
Pork	1819	88.3 %	308	24.9 %
Chicken	205	61.2 %	119	28.9 %
Beef	159	58.0 %	158	54.5 %

Pork production is by far the largest with a production volume of almost 2 billion kg. in 2003. Most of this is exported which makes Denmark the world's largest pork meat exporter. Yet the domestic consumption of pork is also large – almost 3 times the chicken consumption and twice the beef consumption. Large portions of Danish chicken and beef production are exported. Beef meat distinguishes itself from the other two types of meat since more than half of domestic consumption is imported, while only about a quarter of the pork and chicken consumption is imported.

Consequently, Denmark is a small open economy that exports the majority of its meat production, imports more than half of the domestic consumption of beef, and imports around a quarter of its pork and chicken consumption. This implies, among other things, a strong correlation between the meat prices in Denmark and the world market prices.

We perform an empirical analysis that illuminates the dynamic functioning of the Danish meat markets. Specifically, we answer the following five "dynamic" questions:

- What are the reaction times with which prices and quantities begin reacting to a shock in a particular market quantity or price?
- What are the patterns of shock-induced quarterly responses?
- What are duration times of each respondent variable's response?
- What are the degrees of ultimate responses of each respondent variable?
- What are the strength levels and the dynamic timing of causal interrelationships among the modelled variables?

We estimate a vector autoregression (VAR) model of six market-clearing quantity and price variables covering Denmark's pork, chicken, and beef markets. Results from the analysis illuminate the answers to five dynamic questions concerning the way prices and quantities of these three markets interact.

Four sections follow. The first provides an explanation of the econometric model and data. The second and third seek answers to the five dynamic questions through examination of impulse response simulations of selected price and quantity shocks and examination of forecast error variance (FEV) decompositions. The fourth section contains a discussion of the implications for agribusiness strategies and remedial policy. Finally, we provide a summary and conclusions.

The econometric model and data

We specify, estimate, and simulate a quarterly VAR model of the following quantity and price variables for Denmark's three meat markets: pork quantity (QPORK), pork price (PPORK), chicken quantity (QCHX), chicken price (PCHX), beef quantity (QBEEF), and beef price (PBEEF). VAR econometric procedures have been widely established and applied, and are not recounted here. Readers are referred to Bessler's (1984) seminal article, and to prior research by Babula and Bessler (1989, 1990) and Babula and Rich (2001) for procedure details.

Considered a reduced form framework, a VAR model is appropriately considered because evidence rather emphatically suggested that the six time series were stationary, that is I(0) or integrated of order-zero (Hamilton 1994). First, Dickey-Fuller tests performed on the data series suggested stationarity.[2] And second, operating under the well-known possibility of power-related and other problems (discussed in Juselius (2004)) that may generate Dickey-Fuller results that falsely indicate stationarity, we considered a potentially cointegrated model that generated evidence that the system was indeed stationary. More specifically, we followed Babula, Bessler, and Rogowsky (2006) and formulated a rank-restricted cointegrated VAR of the Danish meat markets; implemented a systems-based stationarity test for each of the six endogenous variables; and obtained evidence that all/most variables were stationary

[2] Dickey-Fuller and augmented Dickey-Fuller (DF, ADF) tests were applied to the six series in logged levels. DF or ADF $T\tau$ values ranged from -4.5 to -5.5 for the three quantities. ADF and DF $T\mu$ values ranged from -2.7 to -2.9 for the three prices. Following arguments in Babula and Rich (2001), the 10-percent significance level was chosen. One thereby rejects the null hypothesis of nonstationarity when the pseudo-T values are negative and have absolute values that exceed those of the relevant critical values of -2.58 ($T\mu$) and -3.15 ($T\tau$). In all cases, evidence at the 10-percent level was sufficient to reject the null of nonstationarity.

and/or should be excluded from the error correction space.[3] Such results, along with the Dickey-Fuller test evidence, strongly suggest that the system is likely stationary in logged levels; that a VAR model in logged levels is appropriate; and that modeling the three markets as a cointegrated system is not an issue.

The VAR model posits each of the six variables as a function of 3 lags of itself and of 3 lags of the remaining 5 endogenous variables.[4] The quarterly data set covers the period of 1974:01 – 2004:04. Price data are Danish retail prices, while quantities are the sum of Danish consumption and exports.[5] Even though we use Danish prices, the fact that Denmark is a small open economy which imports and exports large quantities of meat products implies a substantial correlation between world market prices and Danish prices. We estimated the model appropriately with ordinary least squares, and tested it for specification adequacy by applying Ljung-Box Portmanteau and Dickey-Fuller unit root tests on the model's estimated residuals. Results strongly suggest that the model achieved literature-established standards of statistical adequacy.[6]

[3] These protracted cointegration modeling efforts were not included here because of space limitations and are available from the authors on request.
[4] The 3-order lag structure emerged from our application of the lag selection procedure developed by Tiao and Box (1978). We also attempted to incorporate an array of binary variables to capture the effects of post-1973 European Community/Union enlargements, important Danish institutional and meat market events, and apparent observation-specific outlier events. Ultimately, based on statistical significance indicators of coefficient estimates, we included a time trend; three quarterly centered seasonal binaries; and a binary variable to capture the effects of each of the following events: the 1986 EU enlargement; the 1984 institution of Danish milk production quotas; and the 1996:02 discovery of bovine spongiform encelopathy (BSE or "mad cow disease") in the United Kingdom.
[5] Statistics Denmark. 2006. See: www.dst.dk/statistikbanken.
[6] Ljung-Box portmanteau or "Q" statistics generated by each equation's estimated residuals test the null hypothesis of model adequacy, with small Q-values below the critical chi-square value of 13.3 (3 degrees of freedom, 5 percent significance level) suggesting model adequacy. With the VAR model's 6 Q-values having ranged from 0.35 to 0.96, evidence at the 5 percent significance level was insufficient to reject the null of model adequacy, suggesting that all six equations are adequately specified. We followed Granger and Newbold's (1986, pp. 99-101) recommendation not to rely solely on Q-values to discern model adequacy. Following Babula and Rich (2001), we also tested estimated sets of residuals for a unit root with DF tests, with stationarity or absence of a unit root having indicated specification adequacy. One rejects the DF null of nonstationary residuals when DF $T\mu$ values are negative and have absolute values above the -2.89. Since the 6 DF $T\mu$ values ranged from -10.4 to -11.0, evidence at the 5 percent significance level was sufficient in all cases to reject the null of nonstationary residuals and to conclude that evidence supported adequate specification.

Four model simulations with the impulse response function

One aspect of VAR econometrics useful in applied work is the impulse response function. The impulse response function simulates, over time, the effect of a one-time shock in one of the system's series on itself and on other series in the system. The method that converts the VAR model into its moving average representation, a series of nonlinear combinations of the VAR model regression coefficients, is well-known and not summarized here (see Bessler 1984; Hamilton 1994). By imposing a one-time exogenous shock on one of the VAR variables on the system, we may examine the quarterly impulse responses of the other respondent endogenous variables. This enables us to discern what the sample's long run and historical trends would generate as answers to the dynamic questions.

We simulated the VAR model's impulse response function under four shocks: increases in the market-clearing prices of pork, chicken, and beef, and an increase in the market-clearing quantity of chicken. We did not simulate increases in the market-clearing quantities of pork and beef because the heavy international trade dependence of these products renders characterization of the source of such shocks ambiguous. As noted, the quantities of pork and beef, as defined, have substantial trade components: QPORK has a substantial export component, with Denmark being the world's leading pork meat exporter, and QBEEF has a substantial import component that is influenced heavily by EU policy. As a result, one is unable to straightforwardly attribute or characterize a rise in QPORK to supply factors leading to a rise in production, and/or to foreign market demand forces leading to a rise in imports of Danish pork. Likewise, one may not straightforwardly discern if a QBEEF increase arises from Danish domestic demand changes and/or from EU supply and policy changes.[7] Given our limited degrees of freedom, we were unable to disaggregate the two quantities into separate endogenous domestic and trade components – an extension to this study that we must relegate to future research when larger samples are available.

Table 1 and Figures 1-3 summarize the results of the four impulse response simulations. The results, in turn, illuminate the dynamic aspects of a respondent variable's shock-induced effects: direction of responses, response patterns, response durations,

[7] While QCHX has some of these characteristics, the degree of dependence on trade and/or on EU policy changes is not as pronounced as with pork and beef. As seen from the FEV decompositions below, one can more straightforwardly characterize a rise in QCHX than increases in the other two quantities.

response multipliers, and strength of interrelationships among endogenous variables. The elasticity-like multipliers reveal the long run average percentage change in a respondent variable per percentage change in the shocked variable. Sign is important: a positive (negative) sign suggests that the respondent variable's reaction is in the same (opposing) direction as the shock. For example, a negative value of the QPORK multiplier from a PPORK increase reflects a net demand-driven effect over and above a positive supply response, such that the multiplier can at best be considered a lower limit guide for the own-price elasticity of pork.

The model's estimated residuals or innovations may be contemporaneously correlated, and one must incorporate information inherent in such correlations if compromised inference is to be avoided and if VAR econometric results such as impulse responses and forecast error variance or FEV decompositions are to reliably reflect observed patterns (Bessler 1984). Previous research has traditionally employed the Choleski decomposition in order to utilize the information inherent in the contemporaneously correlated current errors (Bessler 1984). We followed this prior work and imposed a Choleski decomposition in order to orthogonalize the current innovation matrix, such that the variance/covariance matrix is identity. Each simulation's decomposition requires an arbitrarily imposed, and presumably theoretically based, Wold causal ordering among the current values of the VAR model's six endogenous variables.[8]

An Increase in Danish Pork Price (simulation 1). On average, each percentage rise in Danish pork price elicits a decline of 0.11 percent in the market-clearing pork quantity. The negative sign on this reduced form multiplier suggests that the demand response dominates any positive supply response. The small absolute value of the response multiplier may reflect either an inelastic demand for pork in the world market, or an elastic demand combined with a fairly elastic supply of Danish-produced pork. QPORK responses take up to two quarters to begin responding and last only a quarter.

The positive multipliers of the prices of chicken and beef suggest that consumers treat these two meats as substitutes with pork. Both prices rise "immediately" (i.e., within

[8] The following three orderings were chosen for the three price shock simulations with the shocked market variables placed atop the ordering, and with the actually shocked variable serving as the ordering's first variable: (1) PPORK, QPORK, PCHX, QCHX, PBEEF, QBEEF; (2) PCHX, QCHX, PPORK, QPORK, PBEEF, QBEEF, (3) PBEEF, QBEEF, PPORK, QPORK, PCHX, QCHX. The ordering for the QCHX shock simulation was QCHX, PCHX, QPORK, PPORK, QBEEF, PBEEF. These orderings follow procedures in Babula and Bessler (1989, 1990) and Babula and Rich (2001).

a quarter after the shock), with PCHX responding for nearly two years, and ultimately rising 0.29 percent for each percentage increase in pork price.

Beef price increases more temperately (by 0.13 percent for each percent PPORK increase), and for a shorter duration. The relatively more modest increase in the price of beef likely reflects influences of the EU beef and veal support regime that has been in place since 1968. Originally, the regime involved domestic price support in times of surplus by EU-financed purchases of beef off the market into intervention stores, and border protection via tariffs preventing the internal EU price from being undermined. The reforms of 1992 and 1999 reduced the role played by intervention storage, and the 2003 reform introduced a decoupling of subsidy and volume of production. However, since most of the data set spans a period of domestic price support and border protection, it is to be expected that beef price response is rather inelastic (Piccinini and Loseby, 2001).

An Increase in Danish Chicken Price (simulation 2). An increase in Danish chicken price elicits an immediate, one-quarter decline in the market-clearing quantity of chicken of 0.43 percent for each percentage rise in the price, with the negative reduced form value again suggesting a dominance of negative demand over a positive supply response. The larger own-price elasticity of chicken demand than pork demand may reflect that consumers are more willing to give up chicken consumption than pork consumption.

The positive PPORK and PBEEF multipliers reflect further evidence that consumers treat the three meats as substitutes. Both prices respond far less than proportionally to each percentage rise in the price of chicken, and for 1-2 quarters.

Not only is the price of beef affected by the increase in the price of chicken, but so too is the quantity of beef: QBEEF increases 0.60 percent for each percentage increase in PCHX. In Denmark, beef cattle production is negligible, and levels of beef meat production are linked closely to the production volume of milk. Hence, EU agricultural policy in terms of the national production quotas on milk governs the Danish production of beef meat. Any change in the market-clearing quantity of beef not ascribed to changes in the production quota most likely relates to changes in the import volume, and since almost 60 percent of total domestic beef consumption is imported, there is room for some variation here. Hence, our results may suggest that Danish consumers view beef as a closer substitute for chicken than pork. The reason could be that beef and chicken are perceived as more as specialty meats than pork, given Denmark's relatively high levels of pork meat consumption.

An Increase in Danish Beef Price (simulation 3). Simulation 3's positive price multipliers of 0.71 for the price of pork and 0.42 for the price of chicken reflect further evidence that consumers treat the three meats as substitutes. The positive multiplier of 0.10 for QPORK reinforces evidence of Danish substitution patterns, with each percentage rise in PBEEF having elicited, on average historically, a modest 0.10 percent rise in pork quantity that clears the market. Yet here, the PBEEF shock's induced increases in pork and chicken prices elicit immediate patterns of increases that last from 16 quarters for PPORK to 23 quarters for PCHX. The far more time-enduring impulse patters elicited here for a PBEEF increase than in the previous simulations is striking and reasons may be twofold. First, our sample included the 1995 British outbreak of Creutzfeldt-Jacob disease that may have generated a longer term substitution away from beef and towards pork and chicken because of a health-based fear of beef consumption that may have taken awhile to reverse. And secondly, since the per-kg price of beef substantially exceeds the prices of pork and chicken in Denmark, there may be an income-based reason where consumers are more reluctant and slow to substitute back to more costly beef products.

The enduring nature of the PBEEF shock's elicited impulse patterns for the price and quantity of pork, and the quantity of chicken[9] are readily plotted in figures 1, 2, and 3. The price variables take on roughly bell-shaped increase patterns for 4-6 years (figures 1 and 3). Policymakers should notice that most of the ultimate effect occurs during the first 1.5-2.0 years.

The response of the quantity of pork elicited by the increase in the price of beef takes a quarter to begin, is most pronounced early-on, then stabilizes into a less volatile pattern later on. Hence, a change in the price of beef, perhaps from a BSE discovery's inherent fear of an outbreak of Creutzfeldt-Jacob disease or from a beef-related EU policy change, will elicit the sharpest pork price effects first, although policy makers do have up to 90 days (one quarter reaction time) to devise any remedial policy deemed desireable.

[9] Note that although the negative sign of the second and third QPORK impulses in figure 2 are not easily explained, these two impulses failed to achieve statistical significance and are not considered. Such erratically signed and insignificant impulses at the onset of such impulse response patterns are indeed common in the literature: see Babula and Bessler (1989, 1990); Babula and Rich (2001).

Figures 1-3 collectively provide implications for Danish policymakers interested in remedial policies or Danish agribusiness agents intent on formulating optimal business strategies to respond to beef price shocks. Such policies and strategies should be quickly implemented insofar as the preponderance of the reaction occurs during the first year and a half of the 4-5 year response cycles.

An Increase in Danish Chicken Quantity (simulation 4). Table 1 suggests that on average historically, each percentage rise in Danish market-clearing chicken quantity elicits a 0.2 percent drop in own-price. The market-clearing price of chicken reacts immediately and lasts for two quarters. A quarter after the shock, the quantity of pork falls 0.1 percent for each percentage rise in QCHX, suggesting further evidence of the two products being treated as substitutes.

Strength of causal relationships among the endogenous variables.

Analysis of forecast error variance (FEV) decompositions is a well-known accounting method for VAR model residuals, and prior research demonstrates that analysis of such decomposition patterns primarily focuses on the fifth dynamic question posed above concerning strength of endogenous variable inter-relationships (Bessler 1984; Babula and Bessler 1989, 1990; Babula and Rich 2001). An endogenous variable's FEV is attributed to shocks in each endogenous variable, including itself. Analysis of FEV decompositions not only provides evidence of the simple existence of a causal relationship among variables, but also illuminates the strength and dynamic timing of such a relationship (Bessler 1984, p. 111). A variable is considered exogenous (endogenous) when large (small) proportions of its FEV is attributed to its own variation and small (large) proportions are attributed to other variables' variation at a particular (here quarterly) time horizon (Bessler, 1984, pp. 111-112). Decompositions of two or more variables may be added together at a horizon for a collective effect. Typically, a variable's FEV is more attributed to own-variation and suggests that the variable is more exogenous at shorter run horizons. On the other hand, a variables behaviour, and in turn suggests higher endogeneity levels for the variable, at longer run horizon (Babula and Bessler 1989, 1990). Patterns of FEV decompositions are summarized in table 2. Due to space considerations, we highlight only the FEV-based findings that are deemed of the greatest relevance and interest. FEV decompositions are more dynamically interesting for the prices, and are examined first. Analysis of patterns for the relatively more exogenous quantities follow.

Danish pork price behaviour is nearly exclusively attributed to own-variation at shorter run horizons when no less than 87 percent of its FEV is so-attributed. Thereafter, PPORK behaviour becomes increasingly endogenous, and by quarter-24, 57 percent of its behaviour is self attributed. In line with the response multiplier of PPORK in simulation 3 above, the next most important explanator of PPORK behaviour appears to be PBEEF, which explains 23 percent of PPORK variation at longer run horizons. This directly coincides with simulation 3's PBEEF shock having generated over 20 quarters of statistically significant pork price increases.

The price of chicken is highly exogenous at shorter run horizons, but becomes more endogenous than PPORK and BEEF at more extended horizons: as little as 29 percent of PCHX variation is self attributed in the long run, as compared with 57 percent for PPORK and 68 percent for PBEEF. The following factors may contribute to an explanation of the relatively higher degree of PCHX endogeneity: EU plays little role in supporting the sector financially; the reproduction cycle is fast such that available chicken meat can increase rapidly; and the cost of feed is more important to total production cost for chicken than for pork and beef. PCHX patterns of FEV decompositions reinforce evidence of strong consumer substitution among the three meats reflected by the impulse response results earlier. More specifically, the percentage of the behaviour of the price of chicken explained by other meat price variation is 20 percent by the price of pork, and 30 percent by the price of beef. This result coincides with the statistically significant and enduring PCHX responses to PPORK increases in simulation 1 and particularly to PBEEF increases in simulation 3.

Danish beef price behaviour is highly exogenous, particularly at horizons of 16 quarters or less when no less than about 71 percent of its variation is self-attributed. As perhaps expected, beef quality is the second most important explanator of beef price behaviour after own-variation by accounting for 16 percent of PBEEF variation at the longer run horizons. The moderate, but steady and time-enduring, PCHX contributions to PBEEF behaviour supports the PBEEF impulses generated by positive PCHX shocks in simulation 2. Variation in the price of pork appears to contribute more to explaining the behaviour of the price of beef at the shorter run horizons, which is consistent with the short and very mild influence that PPORK shocks had on beef price in simulation 1.

There are a number of consistencies with some FEV decomposition patterns and the third simulation's impulse response patterns from a rise in PBEEF. Table 2 suggests that the price of beef has escalating influences on QPORK, PPORK, and PCHX as time horizons are extended beyond a year. Such coincides generally with the time-enduring PPORK, QPORK, and PCHX impulse response patterns that were elicited by the third simulation's positive PBEEF increase.

The three quantities, QPORK, QCHX, and QBEEF are both highly exogenous, with at least 70 percent of behaviour attributed to own-variation in the long run, and modest own-price contributions to explaining the variation in each. The market-clearing beef quantity's high degree of exogeneity and its own-price's modest contributions to behaviour is not surprising, considering the regulatory framework that governs the beef and milk production in Europe. The variation in the quantity of beef is (i) moderately explained by the behaviour of the price of chicken (coincides with the statistically nonzero QBEEF impulses from PCHX shocks in simulation 2), and (ii) negligibly explained by the behaviour of the price of pork (that in turn coincides with the lack of a statistically significant response from QBEEF in simulation 1).

Implications of VAR model results for remedial policy and agribusiness strategy

Perhaps one of the most obvious results for food policy and agribusiness strategy concerns the sensitive cross-market interactions of Denmark's pork, chicken, and beef markets, the products of which appear related through a strong proclivity to substitute among the three meats based on price. These results are of direct relevance for Danish policymakers who focus on food price stability and Danish agribusiness marketers that merchandise all three meats and that are intent on optimal market strategies to cope with shocks such as those simulated above. Danish prices react swiftly to each other, and the response patterns to shocks in Danish pork and chicken markets are short-lived. Shocks to the price of beef have longer lasting effects than shocks to the prices of pork and chicken, and the quantity of chicken. For example, policymakers should note that if one meat price rises, say the price of pork, then substitution will render higher prices for all three meats, which would have an impact on food costs beyond own-market effects. Agribusiness agents should note that an increased quantity of chicken would "crowd out" pork sales through substitution, and they should be thinking of sales receipts in total net terms across markets.

Should a market event substantially shock pork price, Danish policy makers would have some time (up to two quarters) to offset the impacts on the quantity of pork that, once started, are generally short-lived, as well as modest. Should an avian flu outbreak or other market event substantially change Danish chicken price, results suggest that Danish policy makers would have little or no reaction time (a quarter or less) to count on in order to implement any desired policies to offset the short-lived changes in the prices of pork and beef, and the quantity of chicken.

Table 1 and Figures 1-3 have particularly evident policy implications for shocks in beef price, should they arise from a BSE-induced fear of Creutzfeldt-Jacob disease or other market events. Effects on the prices of pork and chicken would be immediate, although policymakers and agribusiness agents would have up to 90 days to devise policies or strategies to offset or deal with changes in the quantity of pork. The immediacy and the tendency for the PBEFF increase-induced pork and chicken price effects to occur early-on (within the first 4-6 quarters) leave far less time than the total impulse pattern duration times (up to six years) may initially suggest for agribusiness agents to devise reactive business strategies or for legislators to head-off effects with any remedial policies. Figures 1-3 clearly suggest that beef price shocks have relatively more enduring impacts than other simulated shocks, and perhaps for reasons discussed above, can take up to 4-5 years to play out.

Conclusions

We have formulated and estimated a quarterly, six-variable VAR model of market-clearing quantities of the Danish pork, chicken, and beef markets. Diagnostic test evidence suggests that the model achieved literature-established standards of statistical adequacy. We then simulated the model's impulse response function under increases in the three prices (PPORK, PCHX, PBEEF) and a rise in the market-clearing quantity of chicken, and carefully examined the dynamic nature of the own-market and cross-market impacts of the shocks. As well, we analyzed patterns of forecast error variance decompositions. We illuminated a number of market-driving parameter estimates and the following dynamic aspects of own- and cross-market inter-relationships that propel these three Danish markets: the reaction times with which the six variables dynamically react to selected imposed shocks; the direction of responses of the five respondent variables to each imposed shock; the dynamic quarterly patterns and duration times of each respondent variable's quarterly responses; a response multiplier for each respondent variable under each shock; and indications of strength of causal inter-relationships among the modeled variables. Results generally fall into two categories: estimates of own- and cross-market parameters, and a number of implications for Danish food policy makers and for agribusiness agents that need evidence-founded knowledge on meat market dynamics to formulate effective and optimal reaction and marketing strategies to shocks that should befall the markets. In addition to extending and clarifying Andersen et. al.'s (2007) work, these results are likely a first-time contribution to the refereed literature on Danish meat markets.

Lower-limit own-price elasticity estimates of Danish demand were estimated: -0.11 for pork and -0.43 for chicken. We estimate a lower-limit of +0.10 as a cross-price elasticity of Danish pork demand from beef price fluctuations. A number of cross-market price transmission response parameters were generated and demonstrate for Danish food economy managers and agribusiness agents the price consequences in other markets, likely through substitution preferences for the three meats, of a price or quantity shock in a market of focus. These are provided in table 1: for example, on average historically, the price of chicken increases 0.29 percent and the price of beef increases 0.13 percent to each percent rise in pork price. These response multipliers suggest that the three meats are close substitutes. So clearly, Danish food policy makers and agribusiness agents that market products with multiple meat bases can appreciate the noticeable consequences on price and demand of a shock's effects not only in its own market, but on other meat markets. The full offsetting effects are seen hypothetically from a rise in pork price when results implied by the model results from simulation (simulation 1, table 1) are carefully considered. While rise in pork elicits a drop in QPORK, and potentially a drop in sales, these effects may be partially offset by augmented beef and chicken sales as both prices rise without changes in beef and chicken quantities.

The manner in which shock-induced quarterly price and quantity responses unfold have valuable insights for Danish policy makers interested in formulating remedial policies to offset undesired impacts of meat market shocks, and for agribusiness marketers of meat products that are intent on formulating optimal marketing strategies to cope with shock-induced impacts on the three meat markets.

Shocks in Danish chicken and pork prices and quantities have own-market and cross-market effects that generally rapidly engage and that occur swiftly, suggesting that policy makers and agribusiness agents have little or no time to react to such shocks with remedial policy or marketing strategy (table 1, simulations 1, 2, 4).

Perhaps because of the health-based fear influences that emerged from the 1995 Creutzfeldt-Jacob outbreak in the United Kingdom and/or from economic considerations of substituting from less costly to more costly products, shocks in the price of beef have noticeably longer patterns of impulse responses than the other three simulations. Positive beef prices shocks elicit rises in the prices of pork and chicken, and the quantity of chicken that last from 4 to almost 6 years. For beef price shocks, policymakers and agribusiness agents have more time to react with policies and strategies. Nonetheless, these patterns of quarterly impulses suggest that the most marked effects occur rather quickly – within the first year and a half after the shock – suggesting that proposed policies and marketing strategies must be more swiftly implemented to be effective than one may think when first regarding the results of simulation 3.

Finally, very strong statistical evidence suggests that Danish consumers are willing and ready to noticeably react to relative meat price shocks by switching to other substitute meats. What sales are lost from, say, a rise in pork price, may be partially offset from increased sales in other markets. Policy makers should see that a rise in pork price could also elicit a wider range of meat-related food price increases with chicken and beef products as consumers switch consumption patterns.

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Table 1 Dynamic quarterly effects of four of impulse response simulations

Respondent variable	Reaction times (quarters)	Direction of responses	Response Patterns	Response durations	Multipliers
	------------------------ Simulation 1: Increase in Danish pork price ---------------------------				
QPORK	2	decline	not relevant	1	-0.11
PCHX	0	increase	Bell-shaped	7	+0.29
QCHX	NSSR	NSSR	NSSR	NSSR	NSSR
PBEEF	0	Increase	not relevant	1	+0.13
QBEEF	NSSR	NSSR	NSSR	NSSR	NSSR
	------------------------ Simulation 2: Increase in Danish chicken price ------------------------				
PPORK	0	increase	not relevant	1	+0.46
QPORK	NSSR	NSSR	NSSR	NSSR	NSSR
QCHX	0	decline	not relevant	1	-0.43
PBEEF	0	increase	not relevant	2	+0.26
QBEEF	1	Increase	not relevant	2	+0.60
	---------------------------- Simulation 3: Increase in Danish beef price ----------------------				
PPORK	0	increase	bell-shaped	22	+0.71
QPORK	1	increase	bell-shaped	16	+0.10
PCHX	0	increase	Bell-shaped	23	+0.42
QCHX	NSSR	NSSR	NSSR	NSSR	NSSR
QBEEF	NSSR	NSSR	NSSR	NSSR	NSSR
	-------------------- Simulation 4: Increase in Danish chicken quantity ---------------------				
PCHX	0	decrease	not relevant	2	-0.20
QPORK	1	decrease	not relevant	1	-0.10
PPORK	NSSR	NSSR	NSSR	NSSR	NSSR
QBEEF	NSSR	NSSR	NSSR	NSSR	NSSR
PBEEF	NSSR	NSSR	NSSR	NSSR	NSSR

Notes: NSSR denotes no statistically significant response

Figure 1. PPORK responses to PBEEF increase

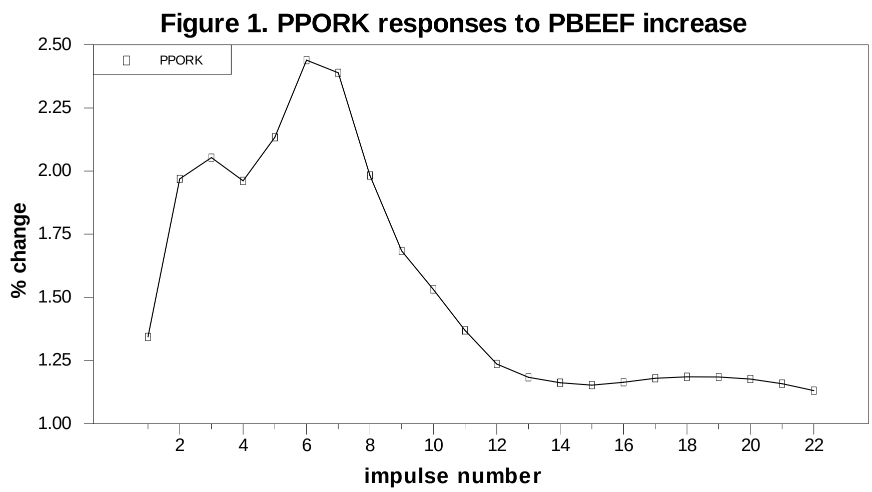

Figure 2. QPORK responses to PBEEF increase

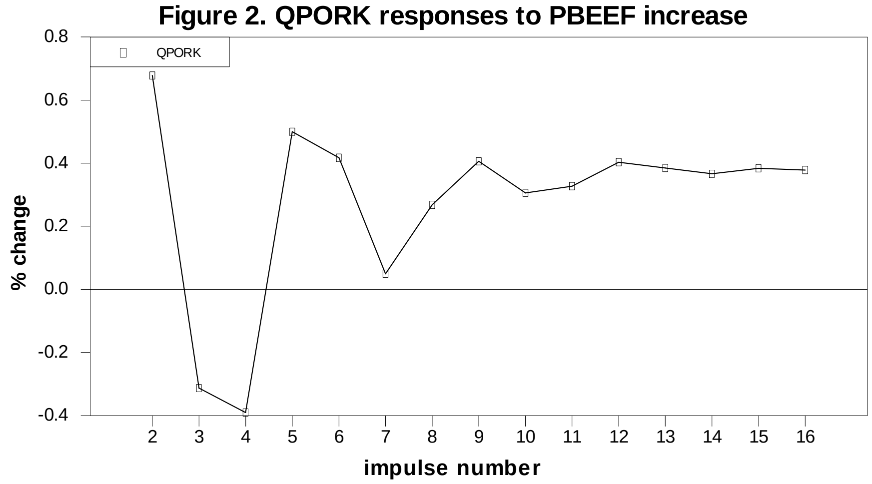

Figure 3. PCHX responses to PBEEF increase

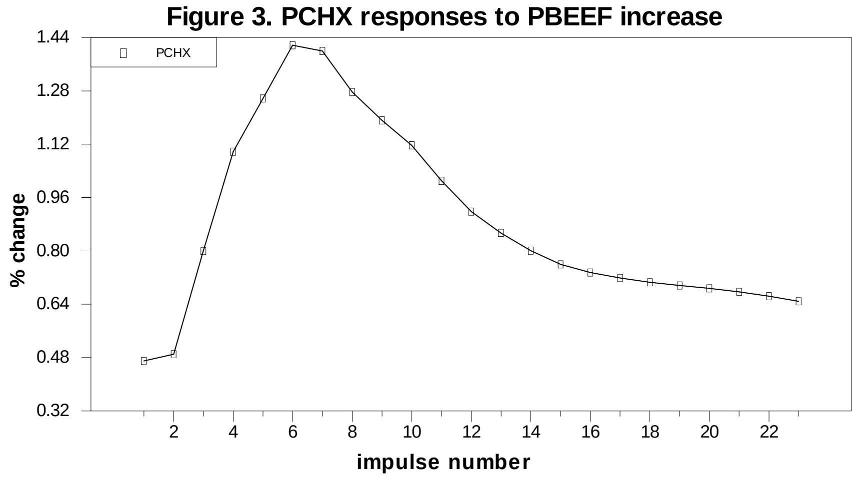

Table 2 Decompositions of forecast error variance

Variable and quarterly horizon	QPORK	PPORK	QCHX	PCHX	QBEEF	PBEEF
	-------------- Percentage of forecast error variance explained by -----------					
QPORK:						
1	93,40	0,29	2,34	0,17	0,69	3,07
2	81,53	8,97	2,80	2,56	1,43	2,71
4	79,85	8,77	3,31	2,55	1,59	3,92
8	75,48	8.50	4,27	4,12	2,51	5,11
16	72,10	8.14	4,27	4,12	3,53	7,85
24	69,72	7.86	4,32	4,13	4,13	9,86
PPORK						
1	0,50	97.84	0,02	0,01	0,95	0,69
2	0,39	95.83	1,25	0,20	0,80	1,54
4	0,92	86.55	1,88	4,83	0,68	5,14
8	0,92	69.78	3,27	9,28	0,83	15,93
16	0,81	60.83	5,45	9,74	2,87	20,31
24	0,91	56.82	6,03	9,42	3,90	22,92
QCHX						
1	,05	0,91	87,97	7,81	2,60	0,65
2	3,65	2,83	82,38	7,34	2,96	0,85
4	4,38	2,99	80,94	7,08	2,90	1,72
8	7,24	3,94	76,34	6,46	2,68	3,35
16	7,95	4,03	74,07	7,00	2,97	3,98
24	8,15	4,01	73,29	6,89	3,06	4,60
PCHX						
1	1,12	11,75	5,42	81,68	0,01	0,01
2	1,33	17,78	5,33	74,30	0,66	0,60
4	3,49	28,50	4,62	55,56	2,18	5,64
8	4,17	28,49	5,38	39,76	2,83	19,38
16	3,82	22,20	9,50	31,71	4,96	27,82
24	3,80	19,94	10,39	29,10	6,27	30,51
QBEEF						
1	5,39	0,64	1,17	6,21	86,59	0,01
2	5,19	0,77	1,32	10,97	81,72	0,04
4	7,98	1,89	1,49	12,06	76,53	0,05
8	8,40	2,36	1,74	11,84	75,11	0,55
16	8,71	2,48	1,96	11,78	74,43	0,64
24	8,75	2,48	2,01	11,77	73,35	0,64
PBEEF						
1	0,34	4,81	0,11	2,97	2,93	88,84
2	0,57	4,48	0,14	3,23	5,18	86,39
4	0,92	3,54	1,98	2,95	10,03	80,59
8	0,65	2,58	4,85	2,90	13,73	75,29
16	0,57	1,68	7,99	3,56	15,60	70,62
24	0,83	1,43	9,62	3,78	16,00	68,43

Working Papers

Fødevareøkonomisk Institut

01/07	Januar 2007	Lill Andersen Ronald A. Babula Helene Hartmann Martin M. Rasmussen	A Vector Autoregression Model of Danish Markets for Pork, Chicken, and Beef
11/06	December 2006	Lars Otto	GRO modellen: Grise, Risiko og Økonomi. Datagrundlag
10/06	December 2006	Lars Otto	GRO modellen: Grise, Risiko og Økonomi. Teoretiske grundlag
09/06	Oktober 2006	Johannes Sauer and Arisbe Mendoza-Escalante	Schultz's Hypothesis Revisited – Small Scale Joint - Production in the Eastern Amazon
08/06	August 2006	Johannes Sauer, Jesper Graversen, Tim Park, Solange Sotelo, Niels Tvedegaard	Recent Productivity Developments and Technical Change in Danish Organic Farming – Stagnation?
07/06	Maj 2006	Johannes Sauer	Prices and Species Deversity – Stochastic Modelling of Environmental Efficiency
06/06	Maj 2006	Jacob Ladenburg Søren Bøye Olsen	Starting Point Anchoring Effects in Choice Experiments
05/06	Marts 2006	Svend Rasmussen	Optimizing Production under Uncertainty. Generalization of the State-Contingent Approach and Comparison with the EV Model